UDC 666.1.053.562.002.2

THE EFFECT OF REGIMES AND METHODS OF GLASS FORMING ON THE TIN CONTENT IN FLOAT GLASS

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Translated from Steklo i Keramika, No. 6, pp. 6 – 7, June, 1998.

The dependence of the tin content in glass is derived as a function of the iron oxidecontent in the glass composition, regimes and methods of forming, and special technological equipment present. The ways of reducing the tin content in glass in the course of glass forming, and correction and prediction of the tin content are considered.

Information about the effect of service parameters of processing equipment on the process of glass ribbon formation by the float method is very important for the optimal choice of the methods improving the technological process and expansion of glass production.

Float glass forming involves a series of complex continuous high-temperature technological processes. Refinement of glass production technology is determined by the level of comprehension of the processes taking place in the melt tank at the glass mass – tin melt – air interface.

Tin transfer from the melt to the glass ribbon results in irreversible loss of critical metal, increases the cost and decreases the glass quality. In the course of forming, the glass ribbon contact the tin in the melt tank. Embedding of tin in the glass takes place throughout the entire temperature region and throughout the whole length of the melt tank [1 – 3].

There is no agreement among researchers regarding the mechanism of tin interaction with the glass surface. Considered are diffusion, physical dissolution, chemical and electrochemical interaction, etc. However, despite the variety of the theories in question there is a consensus that oxygen and some metal impurities (e.g., Fe, Cu, etc.) promote the glass-tin interaction [1 – 4].

In other words, if tin is oxidized or contains impurities, the content of tin in the glass is known to be high. With allowance for this factor the choice of the physicochemical parameters of the float glass forming process is aimed at maximum reduction of the content of oxygen and oxygen compounds in the melt tank [1, 2, 5, 6]. Moreover the melt tank is charged with scrupulous attention to the interstitial content of tin and subsequent regular monitoring of the tin purity. When the content of impurities exceeds the permissible limit, the tin is replaced.

Operating experience shows that tin incorporation in the glass also depends on the processing characteristics of glass forming, the running conditions, condition of the refractory lining, and some other factors.

The tin content in the glass is considered a measure of corporate production culture. The international standard for tin content in glass varies within 0.35 – 0.50 g/m^2. Thus, low values are indicative of well-adjusted technology, whereas a higher tin content points either to poor corporate culture or to the occurrence of a factor which activates a tin — glass interaction.

The present paper is concerned with the effect of regimes and methods of glass forming on the tin content in glass. The work is carried out with data obtained on a EPKS-4000 glass production line (Saratovskii Institute of Glass).

The rates of performance which determine the resulting glass thickness are considered the forming regimes. A comparative analysis of the tin content in glass manufactured by two-stage forming and by the floating ribbon method was performed. The effect of the glass composition (specifically of the Fe content) and the effect of the tin flow spreader and barrier in the tank atmosphere on the tin content are also considered.

Making use of statistical analysis of the data obtained, we derived the regression equation:

$$Y = 0.427 + 0.117X_1 - 0.169X_2 - 0.132X_3 - 0.283X_4 + 0.188X_5,$$

where Y is the tin content in the glass; X_1 is the glass thickness; X_2 denotes the presence ($X_2 = 1$) or absence ($X_2 = 0$) of tin flow spreaders in the melt tank; X_3 indicates the presence ($X_3 = 1$) or absence ($X_3 = 0$) of the barriers in the atmo-

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0361-7610/98/0506-0174$20.00

sphere of the melt tank; X_4 is the method of glass manufacture ($X_4 = 1$ corresponds to the two-stage forming and $X_4 = 0$ to the method of floating ribbon); X_5 is the glass composition ($X_5 = 1$ and $X_5 = 0$ correspond to ferrous oxide content of 0.065% and 0.080%, respectively).

As X_2, X_3, X_4, X_5 are equal to 0 or 1, they are omitted in the regression equation and their effect is rated on a percentage basis. To do this, the tin content in the glass is determined for $X = 0$ and $X = 1$: the tin content for $X = 0$ is taken as 100% and the difference indicates the change in the tin content.

The glass thickness X (mm) and tin content Y (g/m^2) obey the following regression equation:

$$Y = 0.427 + 0.117X,$$

This equation holds true within the X range of 3 – 8 mm. The form of this equation is not new. Naturally, the time of melted tin contact with the glass surface increases as the glass processing rate decreases. The informative value of the derived equation consists in the possibility of quantitative determination and prediction of entrainment of tin characteristic of the EPKS-4000 line with due regard for the physicochemical parameters of the line.

To determine the effect of the tin flow spreader in the melt tank on the tin content in glass, the analysis of the data on the tin content was carried in periods when the spreaders were present and absent in the melt tank.

Data processing revealed that spreaders present in the tank reduce the tin content by 19%. This is attributed to inevitable formation of tin flows which provide for intense transfer of the hot tin to the cold part of the melt tank and vice versa. This results in a temperature decrease along the length of the melt tank and promotes active incorporation of tin into the glass. The spreaders retard circulation of tin flows and contribute to a gradual temperature decrease from the cold to the hot part of the melt tank thus reducing rate of tin incorporation.

The effect of the barrier present in the atmosphere of the melt tank on the tin content in the glass was determined in periods when the barriers were present and absent in the melt tank. It was found that barriers present in the atmosphere of the melt tank reduce the tin content in the glass by 15%. The efficiency of the barriers is also attributed to a gradual temperature decrease along the length of the melt tank and their effect on gas flow in the tank and hence on gas transfer which affects the rate of tin oxide reduction in the tank.

To elucidate the effect of the glass production method on the tin content in glass, a comparative analysis of the data obtained in two-stage glass forming and by the floating ribbon method was performed.

When using the floating ribbon method, i.e., after removal of the gas-air cushion and electromagnetic inductors, the tin content in the glass increases by 31%. This increase is mostly attributable to a 40 – 50°C temperature decrease at the outlet of the melt tank (to about 600°C). At this temperature, tin oxide reduction with hydrogen is hindered and thus activation of the tin/glass interaction is likely.

There is increasing evidence that ferrous iron in glass plays the role of polarizer and activates the tin/glass interaction [1].

Statistical data processing confirms that the tin content follows the iron content in the glass. The calculations show a significant increase in the tin content when the content of ferrous iron increases from 0.065 to 0.085%.

The conclusions made on the basis of many years of observations makes it possible to predict the entrainment of tin and, moreover, to chalk out ways of reducing the tin content in glass manufactured on float-glass production lines.

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